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FOSSIL MAIZE FROM THE VALLEY OF MEXICO

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WITHIN the past decade studies on the origin, antiquity and evolution of maize have received new stimulus from archaeological and palynological discoveries in the southwestern United States and Mexico (Deevey, 1944; Mangelsdorf and Smith, 1949). It now appears well established that a maize culture developed and flourished in the presently semi-arid basins of New Mexico during a period ranging from approximately 3600 B.C., or earlier (Libby, 1951), to approximately 1000 A.D. The morphologically primitive structure of this prehistoric corn, in contrast to its surprisingly recent geologic age, is strong presumptive evidence, though not necessarily proof, that maize originated in the New World and was here developed from its wild state by aboriginal migrants into the American subtropics.

Recently, additional paleontological evidence has been obtained from the Valley of Mexico which indicates a far greater antiquity for the existence of maize in the New World than has yet been revealed by archaeologi-

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cal discovery. The evidence has been secured from a series of deep cores taken in Mexico City, in connection with extensive studies of the sub-surface. These cores have been described in some detail by Sears (1952), and Sears and Clisby (1952).

In the course of analyzing the pollen contents of the cores, Mrs. Clisby observed several unusually large grass-pollen grains in sediments close to the 70 meter level in the Belles Artes boring. The size of the grains (75μ to 135μ by acetylation method) at first appeared to preclude the reasonable possibility that they were derived from native wild grasses then extant in the Valley of Mexico. However, careful study of these fossil pollen grains, including detailed comparison with material in the Harvard Pollen Collections and in the Botanical Museum, suggested three possibilities for their botanical affinity, viz: Tripsacum, Zea or Euchlaena (teosinte)—all of the tribe Tripsaceae. If the grains actually proved to be those of *Zea Mays*, as seems most probable on the basis of their size alone, they would extend the fossil record of Indian corn far beyond our presently known chronology for the existence and dispersal of this remarkable genus of the grasses.

In order to establish a critical basis for identification of the fossil pollen, an extensive study was made of the size-range exhibited by the pollen of various species of Tripsacum and by varieties of maize and teosinte. To sustain essential uniformity in the data, all preparations of both living and fossil grains were prepared by the same technique (modification of Erdtman, 1943), and permanent slides were prepared with glycerin jelly as a mounting medium. A total of eight species of Tripsacum, three collections of teosinte and fourteen varieties of modern maize were chosen for purposes of comparison (Table I). A total of 34 large grass-pollen grains were ultimately

TABLE I

AXIS LENGTH, PORE DIAMETER AND PORE-AXIS RATIO IN TRIPSACUM, TEOSINTE, MODERN AND FOSSIL MAIZE

Species	Number pollen grains measured	Pore-Axis Ratio																											Averages		
		3.0	3.2	3.4	3.6	3.8	4.0	4.2	4.4	4.6	4.8	5.0	5.2	5.4	5.6	5.8	6.0	6.2	6.4	6.6	6.8	7.0	7.2	7.4	7.6	7.8	8.0	9.0	Length Grain, μ.	Diameter Pore, μ.	Pore-Axis Ratio
Tripsacum																															
T. australe No. 1	54			1	8	15	16	11	1	2																			57.4	14.3	1:4.0
" " No. 2	25		1	2	3	5	7	4	2	1																			57.2	14.3	1:4.0
T. dactyloides	50			4	2	8	16	10	6		4																		50.2	12.2	1:4.1
T. lanceolatum	49		3	4	7	7	13	4	11																				49.9	12.5	1:4.0
T. latifolium	50			5	9	15	8	8	4	1																			41.9	10.6	1:1.4
T. laxum	50			2	16	16	13	3																					57.2	14.7	1:3.9
T. maizar	25	1	1	1	2	2	6	4	7	1																			41.7	10.3	1:4.0
T. pilosum	42	1	2	3	6	13	10	5	2																				57.1	14.7	1:3.9
Teosinte																															
Mexico, "Chalco"	50						1		2	5	5	14	9	6	6	1		1											81.8	15.9	1:5.1
Guatemala No. 1	31									2	3	5	5	5	6	3	2												86.4	16.0	1:5.4
Guatemala No. 2	32										4	4	6		4		3	2											79.3	14.7	1:5.4
Maize																															
United States																															
Thompson Flint	50											1			5	7	15	6	6	3	3	2	2						120.7	19.4	1:6.2
Thayer Flint	50														2	3	8	5	8	8	6	5	1	1		1	2		122.8	18.8	1:6.5
Knobless	30															2	2	2	8	12	2		2						118.8	18.2	1:6.5
Mexico																															
Chapalote	50													6	8	4	6	8	4	8	4	2							94.9	15.4	1:6.2
Jala	50											1	1	1	5	8	10	7	6	4	5	1					1		96.6	15.6	1:6.2
Nal-Tel	47														2	4	10	6	5	2	2	4	4	1	2	2	1	2	87.2	13.2	1:6.6
Tabloncillo	50											1	2	3	6	6	9	8	3	6		2	2	2					98.6	16.0	1:6.2
Tuxpeño	50												2	2	6	6	8	4	16				4				2		99.0	15.8	1:6.3
Vandeño	50												4	8	7	10	5	5	3	4			1		1	1	1		97.1	16.1	1:6.0
Zapalote Chico	50											2	2	6	2	6	18	8	6										94.7	15.9	1:6.0
Costa Rica No. 1045	50														2		18	4	4	6	2	4	8	2					104.6	16.0	1:6.5
Peru																															
No. 300	50													5	6	9	10	10	7	3									95.7	15.8	1:6.1
No. 420	50											2		2	12	4	14	8	4		2	2							99.0	16.4	1:6.1
No. 427, "Cuzco"	50												1		5	7	16	8	8	2	1	2							92.1	15.3	1:6.0
Archaeological																															
Bat Cave, Late	50											1	1	1	5	3	7	7	10	6		2	3	1	2	1			88.7	14.1	1:6.3
Bat Cave, Early	10											2			1	2	1	1	1		1	1							93.1	15.2	1:6.1
Fossil, Mexico City	14											1		2	1	3	1	2			1	1	2						95.6	15.5	1:6.2

secured from the lower levels of the Belles Artes core. These lower-depth grains received the most careful study, although an additional 44 large grass-pollen grains from the upper levels of the Belles Artes and Madero cores were also examined by the same procedures.

In the course of making measurements, it early became evident that a wide range in the size of the pollen grains characterizes each of the three genera, a condition possibly indicative of their unusual genetic variability. In Tripsacum, a wide-ranging and common genus of subtropical and temperate North America, the *average* for the long axes of the pollen grain varied between 41.7μ in *T. maizar* and 57.4μ in *T. australe*, with an extreme range in the genus of 33.6μ to 64.0μ. In teosinte, of the three forms examined, the *average* length varied between 79.3μ and 86.4μ, with extremes of 74.0μ and 102.0μ; whereas in maize the *average* range fluctuated between 87.2μ (Mexico "Nal Tel") and 122.8μ with extremes of 72μ and 141.7μ. It is evident that the smaller pollen of some of the varieties of cultivated maize measured in this study fall well within the range of teosinte and close to that of the largest Tripsacum grains. It is apparent, therefore, that size alone cannot be utilized for the critical identification of presumed fossil maize pollen, and that of its relatives, unless a sufficient number of intact grains are available to be measured and plotted on size-frequency curves to show the statistical probability of one of three possibilities. Owing to the small number of individual intact grains from the Mexican borings, however, this procedure was not possible.

Because of the paucity of structural features and the undistinctive sculpture pattern of the pollen exines of the three genera under consideration, it became necessary to attempt some other means of distinguishing the three pollen-types. Consideration of the problem led to one other possibility, viz: a comparison of the ratio in size which exists between the pore (including the annulus) of the pollen grain and that of its long axis (Text Fig. 2).

In order to establish these ratios and to determine their constancy, if any, approximately 50 additional grains were measured from each preparation with respect to these dimensions. In the case of the fossil grains all those exhibiting intact pores were measured. The measurements were averaged and the ratios computed from the averaged value for each species. The results showed encouraging consistency, the ratio of pore to long axis being an unexpectedly conservative value, and, more important to the problem at hand, significantly different among the three species in question. The numerical values computed are shown in Table II.

Although the data are limited to approximately 1000 pollen grains, the differences are so consistent, both with respect to individual grains and averages as well, that the pore-long-axis ratio appears to be a valid means of always distinguishing maize pollen from that of Tripsacum, and in some instances from that of teosinte. It may be noted also in connection with this analysis, that teosinte, a postulated hybrid between maize and Tripsacum (Mangelsdorf and Reeves, 1939), shows an intermediate value both in overall size, and perhaps more significantly, in its pore-ratio. The intermediate value is well in harmony with the postulated hybrid origin of teosinte.

Fossil pollen grains resembling maize, teosinte and Tripsacum in size and in their pore-axis ratios occur in the upper levels of both the Madero and Belles Artes

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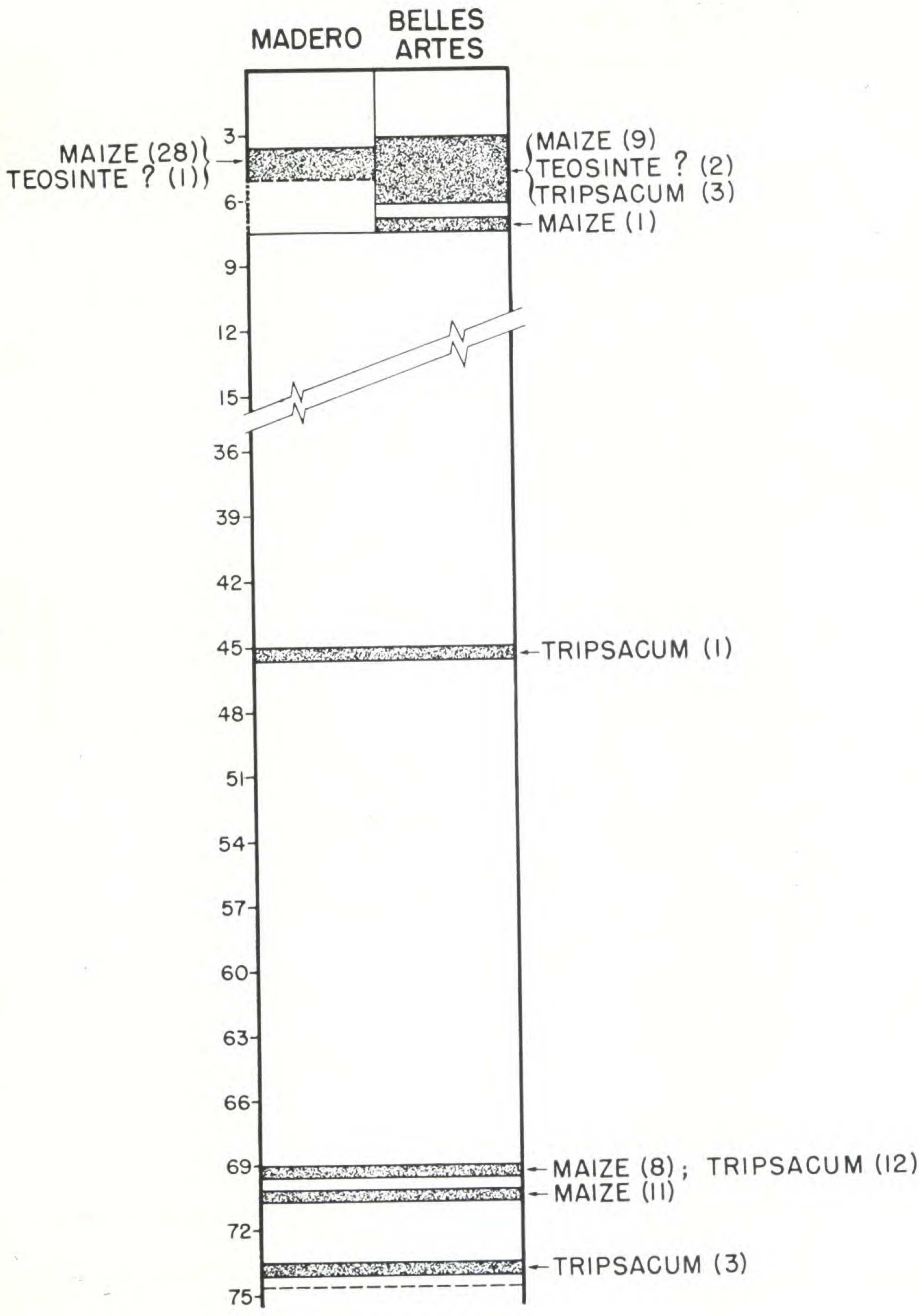
TEXT FIG. 1 (opposite page). Diagram showing the distribution and frequency of maize, teosinte and Tripsacum in samples studied from the Madero and the Belles Artes cores. Note that the Belles Artes core was sampled throughout, the Madero core only to a depth of 5 meters. Numbers in parentheses indicate the number of individual grains. Depth is indicated in meters.



MADERO
BELLES ARTES
MAIZE (28)
TEOSINTE ? (1)
MAIZE (9)
TEOSINTE ? (2)
TRIPSACUM (3)
MAIZE (1)
TRIPSACUM (1)
MAIZE (8) ; TRIPSACUM (12)
MAIZE (11)
TRIPSACUM (3)
3
6
9
12
15
36
39
42
45
48
51
54
57
60
63
66
69
72
75

EXPLANATION OF THE ILLUSTRATION

PLATE XXXVIII. Photomicrographs of fossil, archeological and modern maize pollen grains.

1, Belles Artes core sample number 163, slide number 5. Note pore at extreme upper right, and characteristic folds of the exine. × 435

2, Belles Artes core sample number 148, slide number 1. Pore is clearly visible in upper central portion of grain. × 435

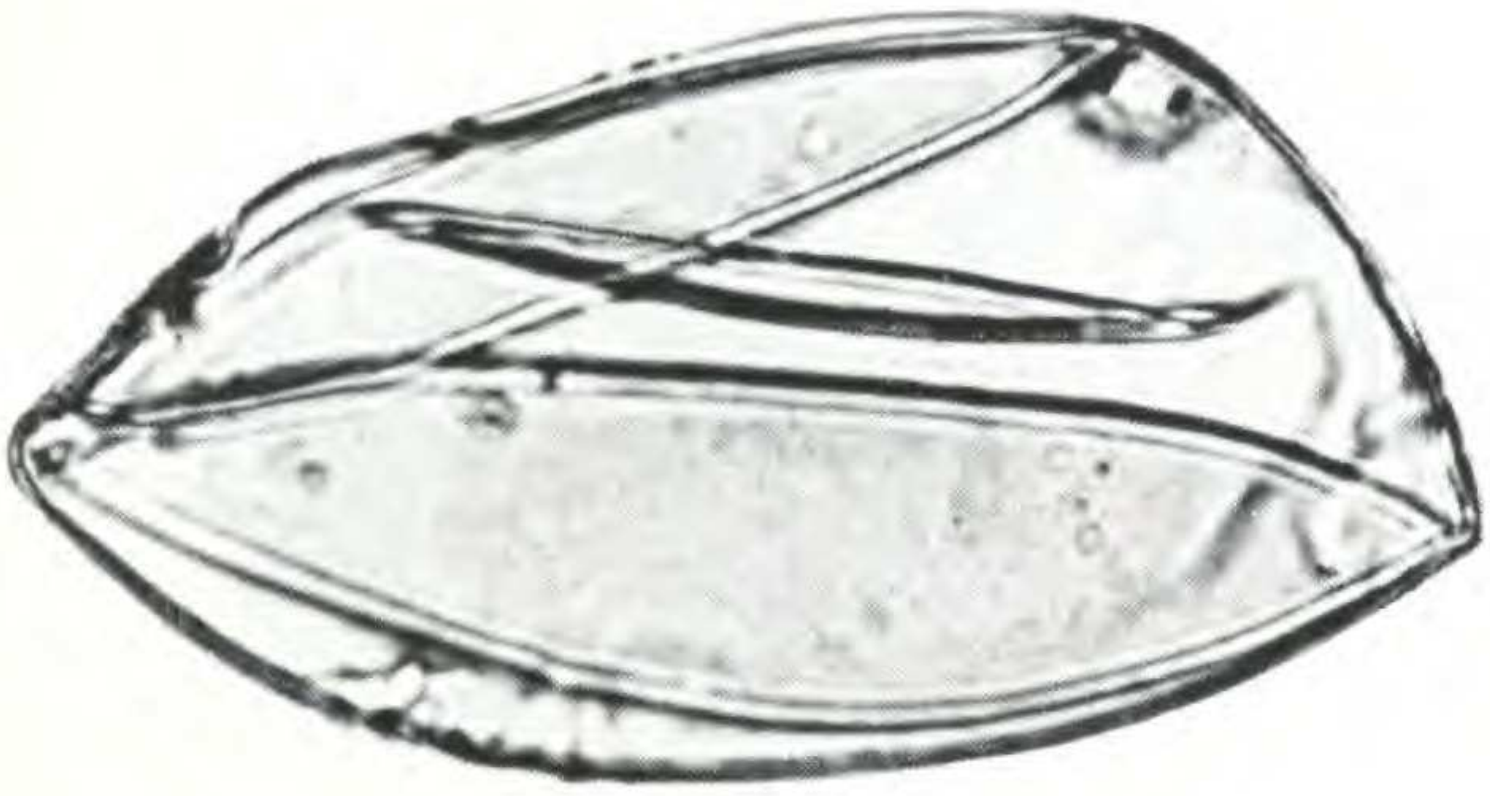
3, Belles Artes core sample number 163, slide number 1a. Pore is visible at lower right. The grain is nearly round, but deeply folded. × 435

4, Bat Cave, New Mexico. Dated by radio-carbon age determination of associated charcoal at 5600 ± years. Note large size of grain and conspicuous pore. × 435

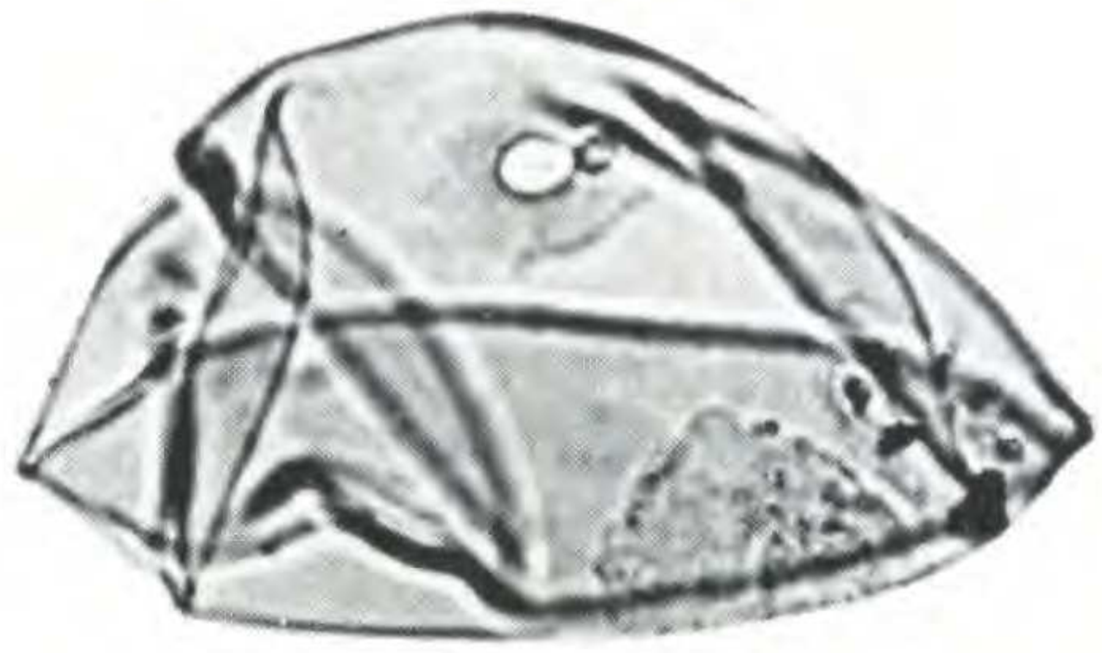
5, Bat Cave, New Mexico. Same source and age as grain shown in fig. 4. × 435

6, Thayer Flint, modern maize, for comparison with fossil maize pollen. Note conspicuous pore in central upper portion of figure. × 435

Plate XXXVIII



1



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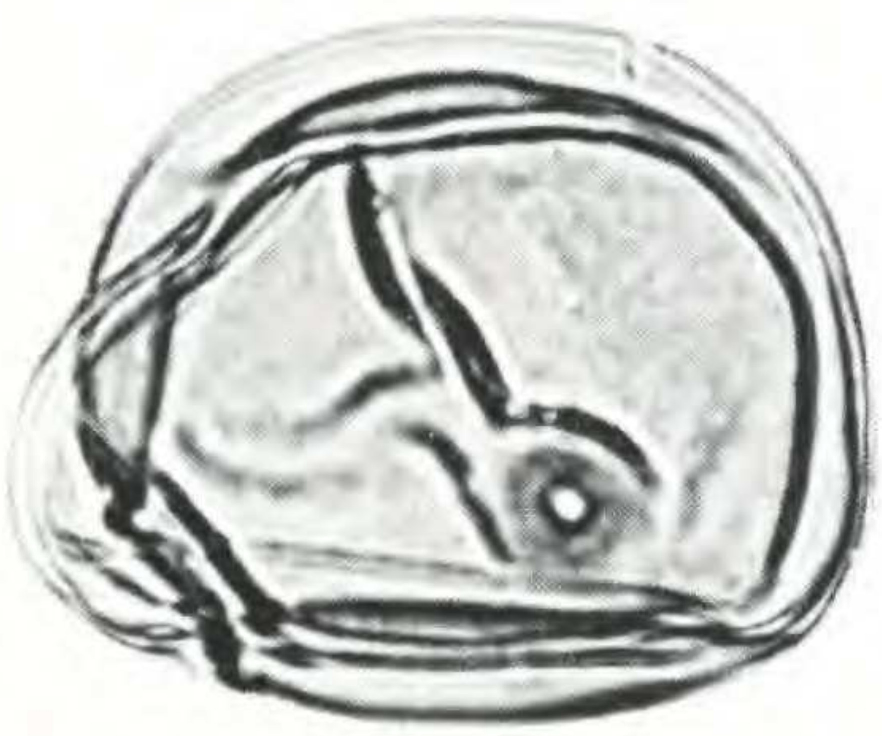

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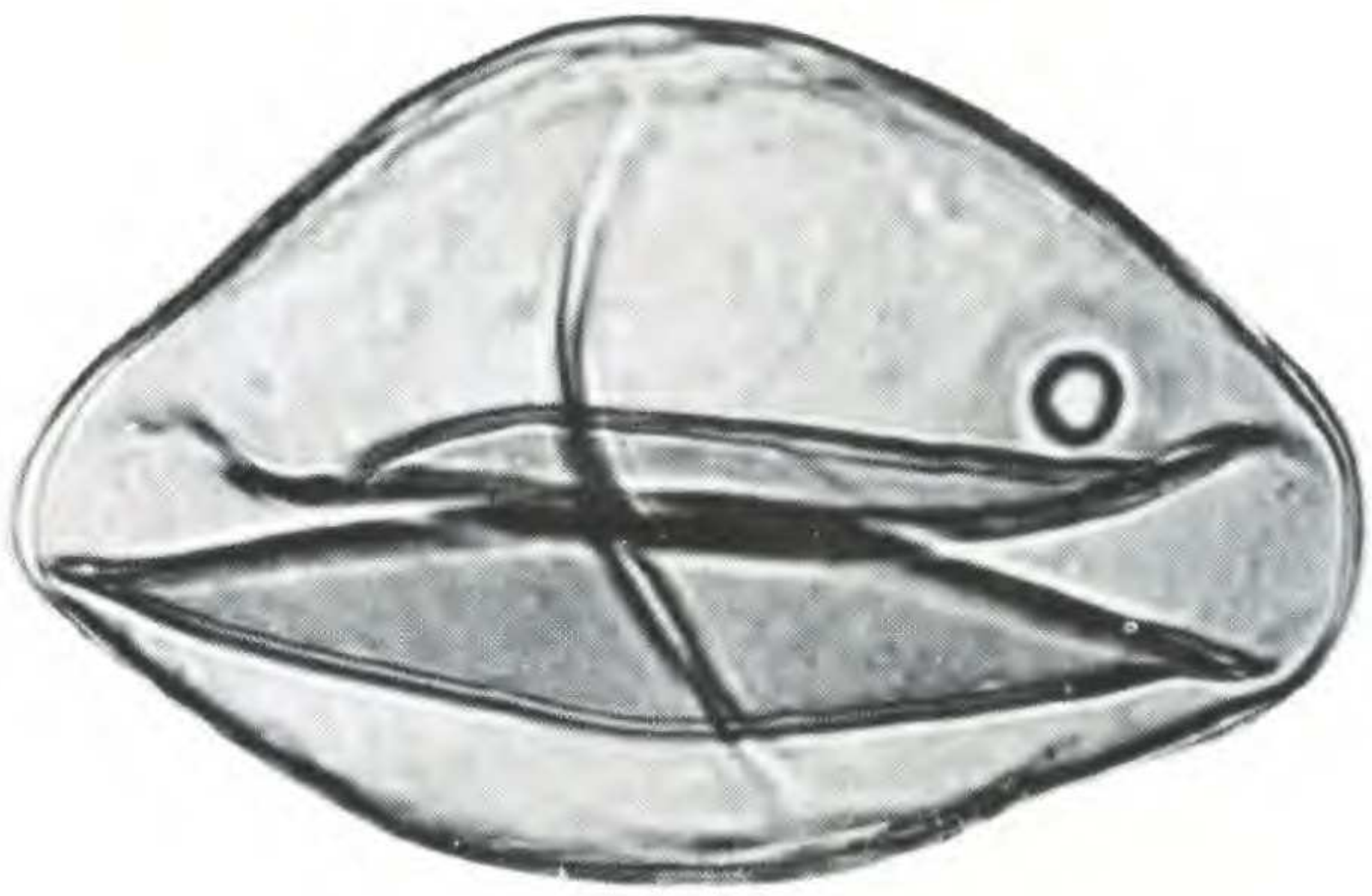

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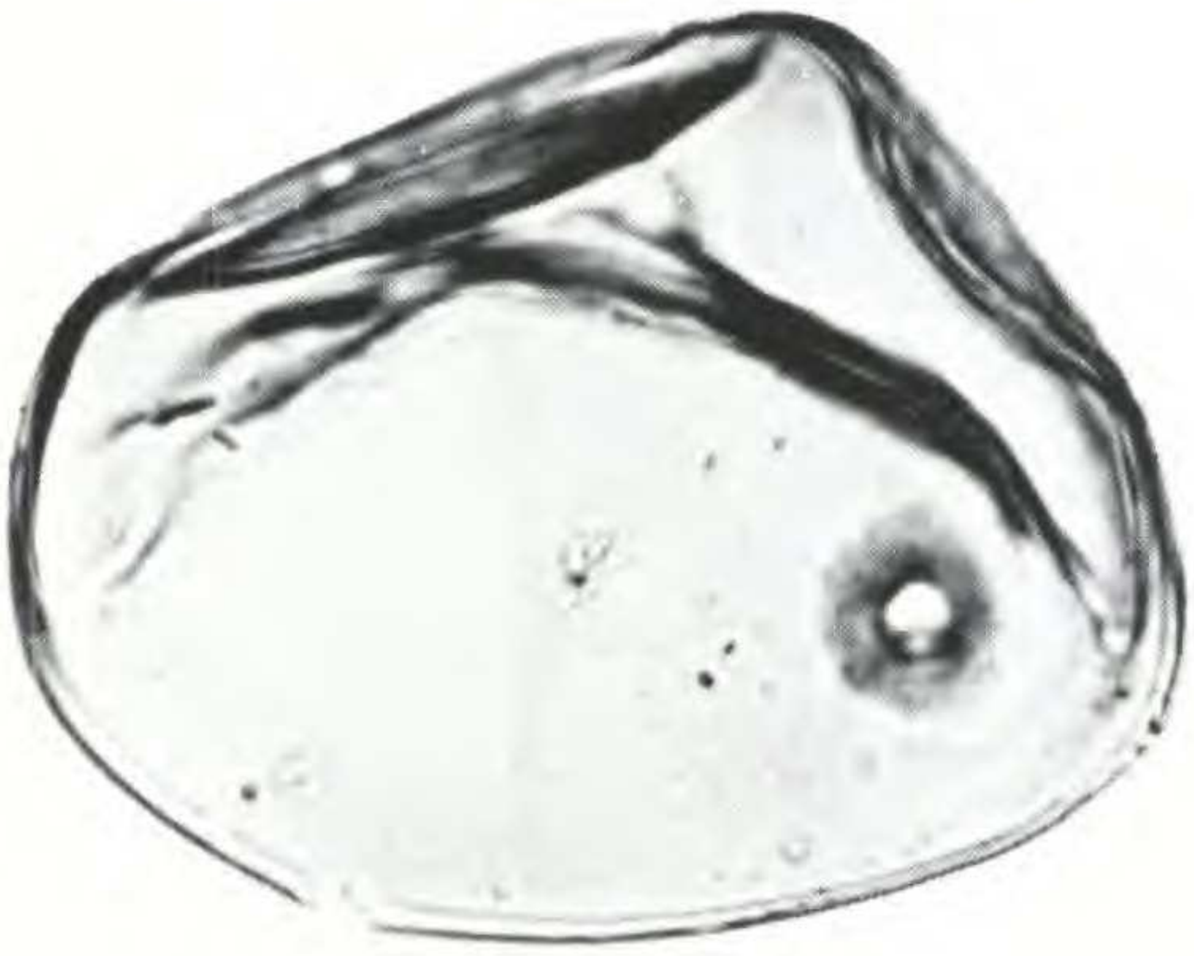

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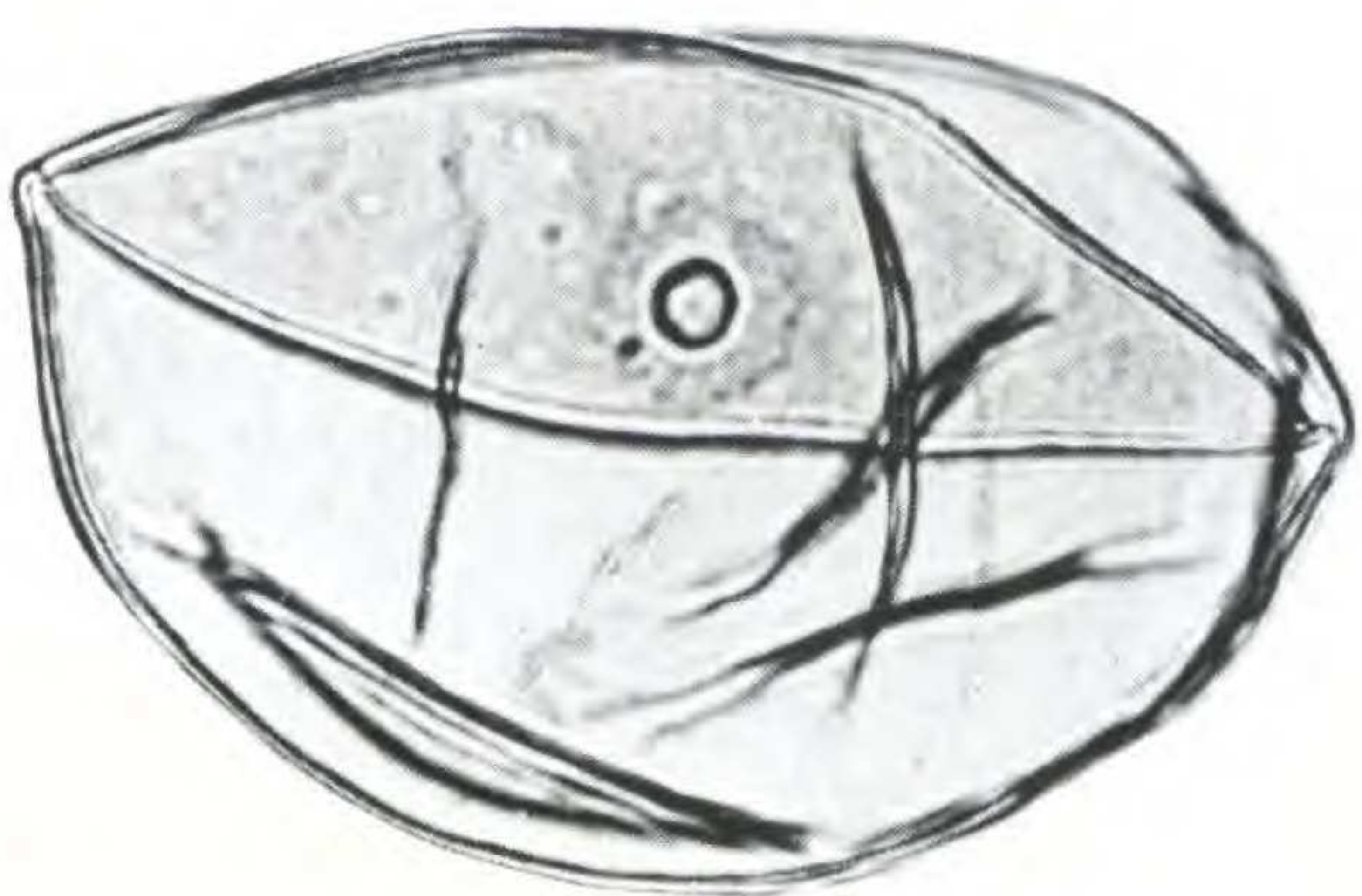
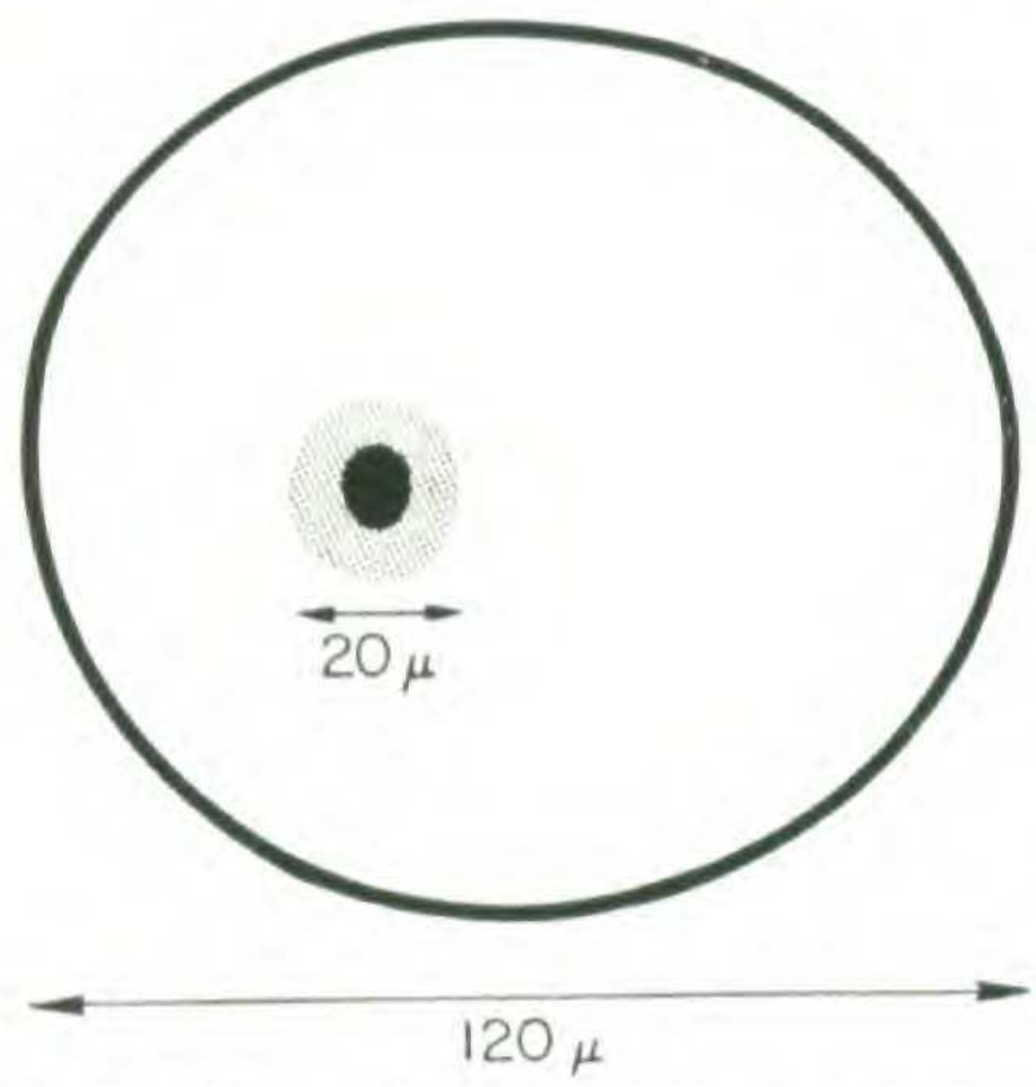


6

cores. The larger grains, 38 in number, from these upper levels (above 6.0 meters) presumably represent the pollen of cultivated maize, and indeed many grains are well within the upper range of several modern varieties. Three grains of intermediate size and pore-ratio in the upper levels (3.3 and 3.6 meters) possibly represent the pollen of teosinte, a common weed in and around the maize fields in the Valley of Mexico today. Three grains conforming to Tripsacum were secured from the upper levels of the Belles Artes core and, interestingly enough, one Tripsacum grain from the 45 meter level of the same core. No pollen grains clearly assignable to teosinte were found below the 3.6 and 3.3 meter levels respectively in either core (Text Fig. 1). This may indicate that teosinte did not become established in the Valley of Mexico until some time after maize-cultivation had begun. However, the total number of grains involved is small and the differences in levels may represent the product of sampling.



TEXT FIG. 2. Diagram showing the pore-axis relationship. Note that the outer borders of the annulus (shaded portion surrounding the pore) are included in the pore measurement. (The ratio is determined by dividing the numerical value, in microns, of the long axis by the numerical value, in microns, of the pore.)

By far the most significant discovery is that of large pollen grains, closely resembling modern maize, in the 69 and 70 meter levels in the Belles Artes core. A total of 19 large grains were secured, 14 of which were sufficiently preserved to permit a pore-axis measurement. Of the 19, 8 are well outside the extreme size-range for teosinte, as determined in this study, and of the remaining 11, four are outside the extreme range of the pore-axis

TABLE II

DATA ON INDIVIDUAL FOSSIL POLLEN GRAINS OF TRIPSACEAE FROM MEXICO CITY CORES

Core	Core Sample Number	Slide Number	Depth Meters	Description				Identification
					Size μ		Pore-Axis	
				Condition	Axis	Pore	Ratio	
Belles Artes	148	1	74.2–74.5	elongated	66.0	13.5	4.8	Tripsacum
" "	"	2	" "	good	55.5	12.0	4.6	Tripsacum
" "	"	7	" "	n.p.v.*	45.0	—	—	Tripsacum
" "	163	1	70.3–70.5	entire	90.0	16.5	5.4	Maize
" "	"	1a	" "	good	75.0	13.5	5.5	Maize
" "	"	2	" "	good	93.0	15.0	6.2	Maize
" "	"	3	" "	n.p.v.	132.0	—	—	Maize
" "	"	4	" "	fragment	79.5	13.5	5.8	Maize
" "	"	5	" "	entire	127.0	17.2	7.3	Maize
" "	"	6	" "	fair	124.0	21.0	5.9	Maize
" "	"	7	" "	fair	124.0	18.0	6.9	Maize
" "	"	8	" "	good	87.0	15.0	5.8	Maize
" "	"	9	" "	n.p.v.	129.0	—	—	Maize
" "	"	10	" "	poor	135.0	18.0	7.5	Maize
" "	165	2	69.7–69.9	good	63.0	16.5	3.8	Tripsacum
" "	"	3	" "	pore eroded	63.0	—	—	Tripsacum
" "	"	11a	" "	eroded	64.5	—	—	Tripsacum
" "	"	11b	" "	elongated	69.0	13.5	5.1	Tripsacum
" "	"	16	" "	elongated	60.0	15.0	4.0	Tripsacum
" "	"	19	" "	elongated	67.5	15.0	4.5	Tripsacum
" "	"	23	" "	elongated	64.5	15.0	4.3	Tripsacum
" "	"	26	" "	poor	55.5	15.0	3.7	Tripsacum
" "	"	39	" "	eroded	60.0	12.0	5.0	Tripsacum
" "	"	41	" "	fair	75.5	13.5	5.5	Maize
" "	"	41a	" "	eroded	54.0	—	—	Tripsacum
" "	"	43	" "	fair	79.5	13.5	5.8	Maize
" "	166	2	69.3–69.5	good	92.5	16.5	5.6	Maize
" "	"	3b	" "	good	73.5	12.0	6.1	Maize
" "	"	12	" "	crushed	70.5	10.5	6.7	Maize
" "	"	18a	" "	good	75.0	15.0	5.0	Maize
" "	"	18b	" "	fair	55.5	12.0	4.6	Tripsacum
" "	"	21	" "	fair	84.0	12.0	7.0	Maize
" "	"	26	" "	pore poor, fragment	54.0	—	—	Tripsacum
" "	"	31	" "	good	105.0	16.5	6.3	Maize
" "	"	47	" "	good	109.5	15.0	7.3	Maize
" "	"	63	" "	pore not clear	66.0	15.0	4.4	Tripsacum
" "	189	1	45.1–45.3	pore not clear, grain elongated	72.0	—	—	Tripsacum
" "	232	1	7.4–7.6	very poor, fragment	135.0	—	—	Maize
" "	234	3	5.9–6.1	good	103.5	15.0	6.0	Maize
" "	235	5	5.1–5.2	good	52.5	12.0	4.3	Tripsacum
" "	"	8	" "	good	112.5	19.5	5.7	Maize
" "	"	9	" "	fair	82.5	15.0	5.5	Maize
" "	"	10	" "	fair	97.5	16.5	5.9	Maize
" "	236	4	4.4–4.6	fair	76.5	12.0	6.3	Maize
" "	"	5	" "	pore not clear	79.5	—	—	Maize
" "	"	7	" "	pore not clear	90.0	—	—	Maize ?
" "	"	8	" "	good	45.0	9.0	5.0	Tripsacum
" "	"	10	" "	n.p.v.	82.5	—	—	Maize
" "	237	11	3.6–3.8	pore not clear	55.5	—	—	Tripsacum
" "	"	12	" "	pore not clear	70.5	15.0	4.7	Teosinte ?
" "	"	13	" "	pore not clear	69.0	12.0	5.7	Maize
" "	"	14	" "	pore not clear	64.5	15.0	4.3	Teosinte ?
Madero	135	1	6.0	elongated good	130.0	15.0	8.8	Maize
"	130	1	5.1	n.p.v.	126.0	—	—	Maize
"	128	1	4.9	good	132.0	21.0	6.2	Maize
"	"	2	"	n.p.v.	96.0	—	—	Maize
"	"	4	"	n.p.v.	87.0	—	—	Maize ?
"	"	6	"	n.p.v.	99.0	—	—	Maize
"	"	7	"	elongated	144.0	—	—	Maize
"	126	1	4.5	n.p.v.	103.5	—	—	Maize
"	"	3	"	good	120.0	19.5	6.1	Maize
"	"	4	"	n.p.v.	99.0	—	—	Maize
"	"	6	"	good	105.0	18.0	5.8	Maize
"	124	1	4.1	pore not clear	140.0	—	—	Maize
"	"	2	"	pore not clear	105.0	—	—	Maize
"	"	3	"	n.p.v.	105.0	—	—	Maize
"	"	4	"	pore not clear	99.0	—	—	Maize
"	"	5	"	fair	135.0	16.5	8.1	Maize
"	120	1	3.3	n.p.v.	127.5	—	—	Maize
"	"	2	"	good	99.0	16.5	6.0	Maize
"	"	3	"	n.p.v.	112.5	—	—	Maize
"	"	4	"	pore not clear	66.0	12.0	5.5	Teosinte ?
"	"	5	"	good	124.0	18.0	6.9	Maize
"	"	6	"	n.p.v.	124.5	—	—	Maize
"	"	7	"	n.p.v.	105.0	—	—	Maize
"	"	8	"	good	124.0	18.0	6.9	Maize
"	119	1	3.1	fair	90.0	15.0	6.0	Maize
"	"	2	"	n.p.v.	100.3	—	—	Maize

* n.p.v. indicates no pore visible for measurement.

ratio for teosinte, although within the upper level of the long axis dimension of teosinte. The existence of these large fossil grass-grains at these great depths calls for an explanation and the following possibilities must be considered.

1. The fossil grains are those of a wild grass, not related to maize or its relatives. This possibility seems quite remote, since, except for the cultivated cereals of the Old World, no grass pollen approaching this size is known.

2. The grains represent contamination occurring in the laboratory. This possibility has been eliminated from consideration by re-examination and re-isolation of grains from additional samples of the core sediments. It may also be ruled out on the grounds of the physical, chemical and optical properties of the fossil grains when compared to modern maize pollen.

3. The grains represent contamination which occurred in Mexico during the core drilling (a) either as atmospheric contaminants or (b) as stratigraphic contaminants during the drilling operations. Possibility 3a can be excluded on the same grounds as possibility 2. Possibility 3b can logically be excluded on the ground that if the large fossil grains were carried down from the upper 6 meter levels, they should be found at intermediate depths. However, the large grains have not been found between the 6 meter level and the 69 meter level, with the sole exception of the one Tripsacum grain referred to previously.

4. The grains are those of either Tripsacum or teosinte

which have increased in size and corresponding pore-axis ratio as a result of preservation under rather unusual sedimentary conditions. There is obviously no way to prove that this is not true, but if it were the case, it would be totally inconsistent with previous extensive experience by numerous investigators in dealing with Pleistocene and Tertiary microfossils.

5. The pollen grains are those of ancient maize. This appears to be the most reasonable interpretation and certainly from the evidence now at hand the only plausible one. The large fossil grains resemble maize pollen not only in their general appearance but in their size, and when it can be determined, in their pore-axis ratio. They differ somewhat from pollen grains of modern maize in possessing a slightly thicker exine and, more significantly, a smoother contour in folding. Although these differences may be due in part to conditions of preservation and post depositional change, it is of interest to note that the prehistoric pollen from Bat Cave, New Mexico shares these properties to some extent; but they are less evident in modern maize (Plate XXXVIII).

Only one of the well preserved grains from the lower levels does not fall within the range of Tripsacum or maize. This grain measures 70.5μ in length, with a pore-axis ratio of 4.7, which is outside the range of maize as determined by our measurements. In pore-ratio it is just within the extreme for Tripsacum and the lower range for teosinte. Whether this one specimen represents an unusually large grain of Tripsacum, other grains of which have been found at this level, or a slightly atypical grain of teosinte, cannot be determined. There remains a re-